

original article

# Evaluation of bio-aerosols concentration in the different wards of three educational hospitals in Iran

Heshmatollah Nourmoradi, Mohammad Mehdi Amin<sup>1</sup>, Maryam Hatamzadeh<sup>1</sup>, Mahnaz Nikaeen<sup>1</sup>

Department of Environmental Health Engineering, School of Health, Ilam University of Medical Sciences, Ilam, Iran. <sup>1</sup>Environment Research Center, Isfahan University of Medical Sciences (IUMS), Isfahan, Iran and Department of Environmental Health Engineering, School of Health, IUMS, Isfahan, Iran.

**Address for correspondence:**  
Dr. Mahnaz Nikaeen,  
Environment Research Center,  
Isfahan University of Medical Sciences,  
Isfahan, Iran.  
E-mail: [nikaeen@hlth.mui.ac.ir](mailto:nikaeen@hlth.mui.ac.ir)

## ABSTRACT

**Aims:** The aim of this study was to evaluate the bioaerosols level in the various parts of three educational hospitals of Isfahan, Iran.

**Materials and Methods:** The collection of bioaerosols (including bacterial and fungal microorganisms) was carried out with one-stage Anderson sampler. The sampling was carried out at the height of 1.5 m from the floor of various hospitals wards (infectious, surgery, urology wards, and operating room). The volume of each sample was determined based on pre-tests carried and was about 50 L. After sampling, the samples were incubated and analyzed. The effect of various environmental conditions including humidity, temperature, and outdoor bioaerosol levels was also investigated.

**Results:** The lowest numbers of fungal and bacterial concentration were obtained in operating rooms of the hospitals and the highest concentration was observed in infectious disease wards of hospital 1 and 2 and surgery ward of hospital 3. The bacterial concentration was observed to be higher in hospital wards than outdoor, except hospitals' operating rooms.

**Conclusion:** The findings showed that the bioaerosols level in the hospitals was relatively high. The higher levels of indoor bacteria than outdoor might be associated with the presence of patients, their activity, unsuitable ventilation, and disinfection. Therefore, environmental monitoring and control measures are required to improve hospital environmental quality especially in the wards with immune deficiency patients.

**Key words:** Bacteria, bioaerosol, fungi, hospital

## INTRODUCTION

Bioaerosols are airborne particles which include living organisms such as bacteria, viruses, fungi, and their metabolites.<sup>[1-3]</sup> The

size of bioaerosols ranges from 0.3 to 100  $\mu\text{m}$ . Particles smaller than 10  $\mu\text{m}$  have received much more attention from the health point of view.<sup>[4]</sup> Bioaerosols constitute 5-34% of the indoor air pollution.<sup>[5]</sup> Bioaerosols' adverse health effects include infectious and respiratory diseases, acute toxic effects, allergy, and cancer.<sup>[2,3]</sup> Bioaerosols enter the human body via several routes such as inhalation, ingestion, and skin contact. Inhalation is the most important route for transmission of bioaerosols into the body. Unlike chemicals, exposure to bioaerosols does not have any health threshold due to the type of microorganisms, entrance way, and difference in individual immune response.<sup>[6]</sup> Nowadays, hospitals and occupational

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infections are growing due to the exposure to bioaerosols. Therefore, it is necessary to investigate the bioaerosols, extensively.<sup>[7]</sup> The presence of bioaerosols in hospital wards is due to the presence of patients, their activities, inadequate ventilation, and incorrect disinfection.<sup>[8]</sup> *Penicillium* and *Aspergillus* species, *Legionella pneumophila*, *Francisella tularensis*, *Bacillus anthracis*, *Yersinia pestis*, *Trichoderma* species, *Mycobacterium tuberculosis*, and *Variola* virus are the most important microorganisms which caused disease through the air.<sup>[3]</sup> Air-borne nosocomial infections are the main causes of pneumonia and surgical wound infection,<sup>[9]</sup> especially in immunocompromised patients.<sup>[10]</sup> Air conditioning and filtration equipment can be used to reduce the airborne fungi concentration.<sup>[11]</sup> Decrease in bacteria concentration in the air of the operating room also reduces the post-infection of surgery wounds. Bioaerosols monitoring in hospitals may provide useful information for epidemiological studies of nosocomial infections and control of bioaerosols.<sup>[12,13]</sup> Given the importance of monitoring of bioaerosols in health care settings, the aim of this study was to investigate the bioaerosols concentration in the air of various parts of three educational hospitals of Isfahan University of Medical Sciences, Iran.

## MATERIALS AND METHODS

### Location

This study was carried out on the microbial quality of air of three educational hospitals of Isfahan, Iran, in 2010. The operating room, surgery, urology, infectious, and special care wards of the hospitals were investigated. Also, outdoor sampling was done to find out the relationship between the bioaerosols concentration in the outdoor and indoor air. 130 samples of the air, including 5 times for any ward (65 fungal samples and 65 bacterial samples), were biweekly collected.

### Sampling method

A one-stage Anderson sampler was used for bioaerosols sampling [Figure 1]. The sampler was located at a height of about 1.5 m from the floor (at the human breathing zone). Sampling was carried out for 5 min at the rate of 10 L/min (sample volume was determined based on pre-tests). After sampling, the samples were quickly transferred to the laboratory using a cold box and incubated. Temperature and humidity measurements were carried out using a portable instrument (KIMO, AMI 300) to determine the association between the bioaerosol concentrations and environmental conditions.

### Culture medium

Sabouraud dextrose agar medium (Merck Co, Germany) containing chloramphenicol antibiotic was used for the determination of fungal bioaerosols. The fungal samples were incubated at ambient temperature (25°C) for a period of 5-7 days. The fungal colonies were counted and identified using a microscope (with a magnification of 40). Trypticase Soy Agar (TSA) containing nystatin (250 mg/L) was also provided from Merck Co. Germany and used for the sampling of bacteria. The

concentration of bioaerosols has been reported as cfu/m<sup>3</sup>. The bacterial samples were transferred to the incubator (37°C) for a period of 24-48 h. Bacterial colonies were identified using the Gram staining and biochemical tests (catalase and coagulase).

## RESULTS

Figures 2 - 4 show the mean number of fungi and bacteria in the various parts of the hospitals air. The lowest fungal and bacterial colonies in the air of three hospitals were found in the operating room.

The highest concentration of bacteria and fungi was detected in the infectious diseases ward of the hospitals 1 and 3 and surgery ward of hospital 2. The average number of fungal spores in the outdoor air of the hospitals was higher than the average number of fungi in the air of various parts of the hospitals. Whereas, the number of bacterial colonies in the outdoor air of the hospitals was lower than the air of various parts of the hospitals, except in the operating room. Table 1 shows that the most common fungal species in the indoor air of the hospitals were *Penicillium* spp. and black fungi (mostly, *Alternaria* spp. and *Cladosporium* spp.), respectively. The most common fungi in the outdoor air were *Penicillium* spp. (40.6-60.2%) and black fungi (35.5-48.1%) similar to the hospital wards. *Staphylococcus aureus* (21.71%), negative-coagulase *Staphylococcus* species (77.3%), and Gram-positive bacilli with side spores (0.99%) constituted the bacterial bioaerosols in the air of various parts of hospital 1. The *S. aureus* and negative-coagulase *Staphylococcus* species in hospital 2 were 22.73% and 77.27%, respectively. The *S. aureus*, coagulase-negative *Staphylococcus*, and *Streptococcus* species in the air samples of the hospital 3 were 20.85%, 78.2%, and 0.95%, respectively.

## DISCUSSION

Bioaerosols, smaller than 10 µm, are of greatest concern for human health. Exposure to bioaerosols in hospitals may result

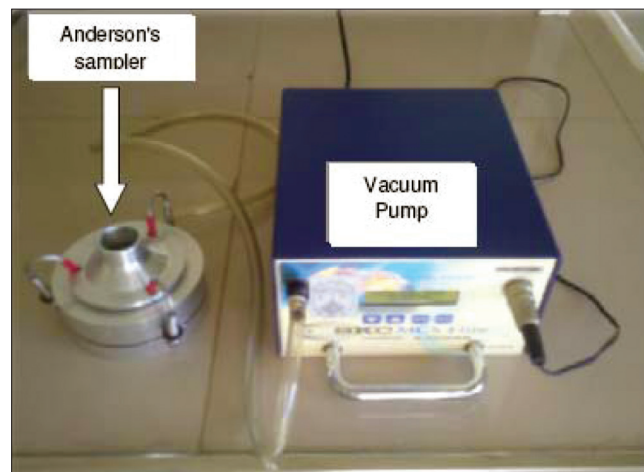
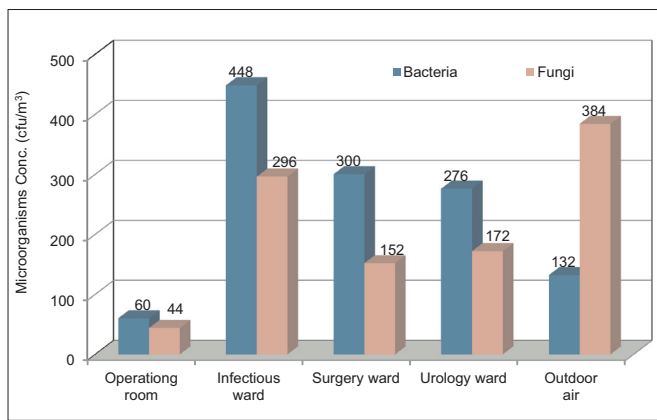
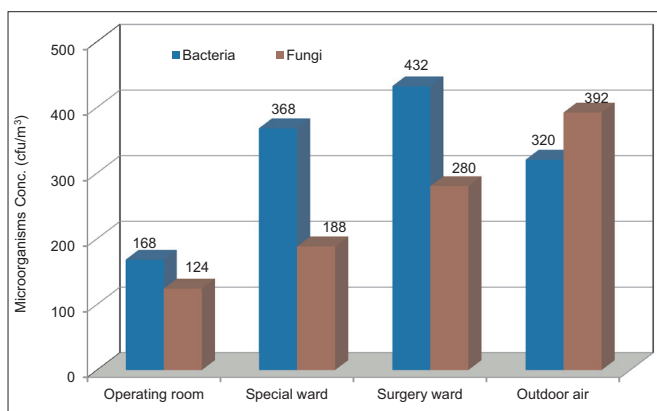


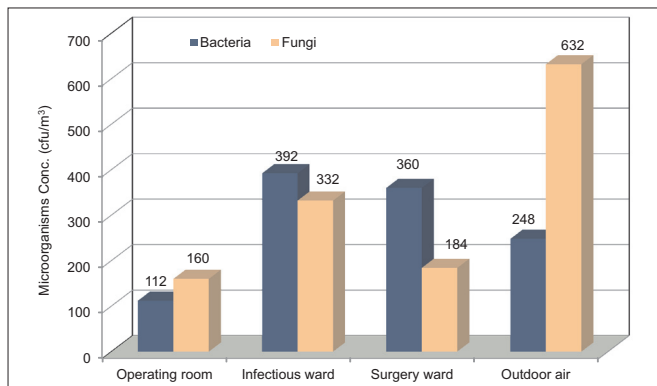
Figure 1: Anderson sampler



**Figure 2:** The number of fungi and bacteria in the air of hospital 1 wards



**Figure 3:** The number of fungi and bacteria in the air of hospital 2 wards



**Figure 4:** The number of fungi and bacteria in the air of hospital 3 wards

in infection, especially in immunocompromised patients. Figures 2 - 4 show the average number of fungi and bacteria in the air of various parts of the hospitals. The results show that the lowest fungal and bacterial contamination was found in the operating rooms. The number of bioaerosols in the operating room of the hospitals showed that hospital 1 has a better quality ( $P < 0.05$ ). Azizifar *et al.* reported that the lowest fungi level was found in the operating room ( $94 \text{ cfu/m}^3$ ) of Qom Kamkar hospital, Iran.<sup>[13]</sup> Perdelli *et al.* also

**Table 1: Frequency of predominant fungi in the air of various wards of the hospitals**

Hospital	Fungus type			
	<i>Penicillium</i> (%)	Black fungi (%)	<i>Aspergillus</i> spp. (%)	Other (%)
1	44.05	40.48	1.79	13.69
2	58.33	35.90	0	5.77
3	49.11	39.05	2.37	9.47

reported that the lowest amount of fungal contamination was in the operating room (operating theater) of hospital air ( $12 \pm 14 \text{ cfu/m}^3$ ).<sup>[14]</sup> With regard to sterilization process of operating rooms, bioaerosols concentration should be very low. The presence of bioaerosols in the operating room may be due to the inefficiency of ventilation and sterilization systems. The results of Favero *et al.* showed that the emission of microbial contamination from skin, hair, and respiratory tract of the person is one of the important causes for the presence of bioaerosols in the air of the operating rooms.<sup>[15]</sup> The highest load of bacterial contamination in hospital 1 was detected in the infectious ward which was equal to  $448 \text{ cfu/m}^3$ . High concentration of bacteria in the infectious ward may be due to the presence of patient with infectious diseases and inadequate ventilation in this section. Azizifar *et al.* have also reported the highest fungal contamination in the infectious ward of the Qom Kamkar hospital ( $300 \text{ cfu/m}^3$ ).<sup>[13]</sup> ANOVA statistical analysis results do not approve significant difference between the mean total number of bacteria and fungi in the air of hospitals 1, 2, and 3 ( $P > 0.05$ ). The statistical test results also showed a significant difference between the concentrations of fungi and bacteria in the air of various parts of hospital 1, except the urology and surgery wards ( $P < 0.05$ ). There is also a statistical difference between the average number of fungi and bacteria in the operating room and other wards of hospitals 2 and 3 ( $P < 0.05$ ). Statistical analysis also approves the high concentration of bacteria in the air of wards compared to outdoor air, except the operating room ( $P < 0.01$ ). This may be due to the presence of patients, their activities, inadequate ventilation, and unsuitable disinfection of the hospitals.<sup>[8]</sup> But the average number of fungi in the outdoor air is higher than various parts of the hospital. The presence of fungi spores in the indoor air may be due to contact with the outdoor air. However, the number of fungi must be less than  $15 \text{ cfu/m}^3$  in the hospitals equipped with a filtration system.<sup>[16]</sup> Air humidity and temperature were measured to evaluate the effect of environmental factors on bioaerosols concentration. Pearson's correlation analysis showed that the environmental conditions (humidity and temperature) have no significant effects on the bioaerosols levels ( $P > 0.05$ ). Obbard *et al.* found a significant relationship between the concentration of bacteria, population density, and air humidity. They also realized that there is a relationship between the outdoor and indoor bacteria concentration.<sup>[17]</sup> However, in the current study, statistical analysis did not confirm a correlation between the outdoor and indoor bioaerosols concentration

( $P > 0.05$ ). Table 1 shows the frequency of dominant fungal species separated from the hospitals' air. The results show that the most common fungi separated from the hospitals' air were *Penicillium* and black fungi. *Aspergillus* species accounted 1.79-2.37% of fungal bioaerosols in the current study. Li *et al.* reported that the most common fungal species in the operating rooms of Taiwan hospital as *Penicillium* spp.<sup>[18]</sup> Ekhaise *et al.* also found that *Penicillium* spp. and *Aspergillus* spp. were the most fungal species in the air of Government Owned hospitals in Benin City, Nigeria.<sup>[19]</sup> Mahdavi *et al.* reported that the most common fungus in the air of Babol hospital (Iran) was *Penicillium* spp.<sup>[20]</sup> Hashemi *et al.* also found that the most common fungal species were *Cladosporium* and *Penicillium* in the Shariati hospital of Tehran, Iran.<sup>[21]</sup> Analysis of the bacterial aerosols in the Shariati hospitals showed that the most common bacterial species were negative-coagulase *Staphylococcus* species (77.27-78.2%) and *S. aureus* (20.85-21.71%). Ekhaise *et al.* reported that the average number of bacteria in the air of a hospital in Nigeria was 15-52 cfu/m<sup>3</sup> and *Staphylococcus* was the most common bacteria.<sup>[19]</sup> According to a study by Pastuszka *et al.* on the air of a hospital in Poland, the average number of bacteria was reported in the range of 100-1000 cfu/m<sup>3</sup> and the most common bacterial species were *Staphylococcus* and *Micrococcus* (57-78%).<sup>[22]</sup>

## CONCLUSION

According to the results obtained in the current study, the bioaerosols concentration in the above hospitals is relatively high. The higher number of bacteria in the hospitals than outdoor air can be attributed to the patients, their activities, inadequate ventilation, and incorrect disinfection. Therefore, some measures including installation of filter in the inlet air to the hospital wards, avoiding opening windows for natural ventilation and regular disinfection of the hospital, are suggested to reduce the concentration of bioaerosols and improve the air quality. Because of the presence of bioaerosols in the operating room, it is also recommended that the air filters and sterilization system (UV lamps) be under constant control to ensure their proper operation.

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